Comment on 'Spin Decoherence in Superconducting Atom Chips'

Stefan Scheel, E. A. Hinds, and P. L. Knight
Quantum Optics and Laser Science, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2BW, United Kingdom

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We comment on a recent paper [Phys. Rev. Lett. **97**, 070401 (2006)] concerning rubidium atoms trapped near a superconducting niobium surface at $\sim 4\,\mathrm{K}$. This seeks to calculate the rate of atomic spin flips induced by thermal magnetic noise. We point out that the calculation is in error by a large factor because it is based on the two-fluid model of superconductivity. This model gives a poor description of electromagnetic dissipation just below the critical temperature because it cannot incorporate the case II coherences of a fuller quantum theory.

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A recent publication [1] discusses atoms magnetically trapped near a superconducting surface and attempts to calculate the spin flip rate due to thermal magnetic noise. The Letter recounts the formalism developed in [2, 3], largely verbatim, and then applies it to the two-fluid model of superconductivity. This leads the authors to conclude that Rb atoms near a superconducting niobium surface enjoy a lifetime increase of 10^5 as the temperature is lowered by one or two degrees below $T_c \simeq 8\,\mathrm{K}$. This disagrees dramatically with previous estimates of the effect [3, 4] that were based on measured electromagnetic dissipation in niobium. Here we point out that the use of the two-fluid model has led to an erroneous result.

In the two-fluid model, the density of the normal component scales as $(T/T_c)^4$. As the temperature drops, this rapidly suppresses all dissipative processes, giving a very large derivative just below T_c. This is precisely the behavior shown in figure 2 of [1]. However, it is well known that the two-fluid model provides a poor description of nuclear relaxation and electromagnetic absorption in the temperature range just below T_c. This is because of quantum interference effects in the relevant low-energy scattering processes, which lead to the so-called case II coherence factors. These cause the dissipation to *increase* as the temperature is lowered below T_c before it declines again in the low temperature limit. This behavior was first observed in the case of nuclear-spin relaxation [5], and is called the Hebel-Slichter peak. Chapter 3 of Tinkham's book [6] gives a very accessible introduction to this subject. There he points out that "the ability of BCS pairing theory, with its coherence factors, to explain this difference [from the two-fluid model] in a natural way was one of the key triumphs which validated the theory".

More recently, the same type of behavior has been confirmed experimentally for electromagnetic absorption [7], where the case II coherence factors have been observed in superconducting Nb and Pb over the range $T_c/4 \lesssim T < T_c$. These are not pure BCS superconductors but have to be described by the strong-coupling Eliashberg theory. Nevertheless, their temperature-dependent absorption exhibits the same type of peaked behavior, which disagrees with the two-fluid model used in [1].

The predictions for spin flip lifetimes made in previous papers [3, 4] are based on experimental results which explicitly confirm the existence of the case II coherence factor in niobium [7]. The main enhancement of lifetime at $4\,\mathrm{K}$ compared with room temperature (~ 100) is due to the smaller number of thermal photons per mode. In addition Ref. [3] estimates that the lifetime should increase by a further factor of ~ 10 as the temperature is lowered from T_c to $T_c/2$, in accordance with BCS theory and with the experimental evidence. By contrast, Ref. [1] predicts an increase of 10^5, not this factor of 10, when cooling only by one or two degrees below T_c. This is an artifact of the two-fluid model. Although the more realistic calculation gives a smaller enhancement of the lifetime, the effect is nevertheless exceedingly significant for the future of superconducting atom chips [8] as low-decoherence quantum devices.

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